

Report as of FY2009 for 2009GU156B: "Impacts of Land Cover Change on Groundwater Quality in Guam"

Publications

- Conference Proceedings:
 - ◆ Wen, Yuming, 2009, Change Detection of Land Cover in Northern Guam, Proceedings of the 6th International Symposium on Digital Earth: Digital Earth in Action, September 9 – 12, 2009, Beijing, China, p45
- Other Publications:
 - ◆ Wen, Yuming and Maria Kottermair, 2009, Water Quality Data Preparation for GIS Analysis, 30th Annual College of Liberal Arts and Social Sciences (CLASS) Research Conference, University of Guam, March 10, 2009, Abstract p7

Report Follows

PROJECT SYNOPSIS REPORT

Project Title: Impacts of Land Cover Change on Groundwater Quality in Guam

Problem and Research Objectives

Guam, an unincorporated U.S. territory in the western Pacific, is the largest (about 541.3 km²) and southernmost island in the Mariana Islands. Ground water supplies about 80% of the drinking water for the island's about 180,000 residents and over one million visitors annually. In northern Guam, water is pumped from over 100 wells, most of which are located in the northern Guam. Because of run-off and human activities, and unreliable drinking water delivery systems and management, the potential for contamination is high.

At its 12 September 2008 meeting, the WERI Research Advisory Council for Guam identified *impact of past use of banned pesticides and organic substances on surface and groundwater*, and *identification and mapping of the sources, locations, movement, and fate of petroleum and other groundwater contaminants under northern Guam* as some of the highest priority research needs for Guam. Based on the above statement, groundwater quality is a main concern in Guam. This project aims to address the above mentioned issue. The water quality data from drinking wells in Guam from 1996 to 2009 are available. Landsat Satellite images of 1973 and 2001, and the 2006 QuickBird image are available. The project incorporates all the data collections from Guam Waterworks Authority (GWA) into GIS data formats for each contaminant that has so far been detected. The relationships between land cover change and some commonly occurring contaminants, e.g. fecal coliforms, chlordane, tetrachloroethylene (PCE) and trichloroethylene (TCE) are evaluated.

The main objectives of this project are listed as follows:

1. Preprocessing of Landsat images for derivation of land cover information;
2. Classification of land cover information from available Landsat and QuickBird images;
3. Evaluation of the relationship between land cover change, particularly human-induced activities and groundwater quality;
4. Temporal and spatial changes in the distribution and abundance of frequently occurring chemical and biological contaminants

Methodology

GIS, remote sensing, spatial analysis and geospatial statistics are used to complete the project. GWA provides 1996-2009 water quality data for all drinking water production wells in service between 1996 and 2009. Well locations, and sub-basin information are also available from this agency. Landsat image of 1973 and QuickBird image of 2006 are used. The GIS Lab at the Water and Environmental Research Institute (WERI) is equipped with the state of the art computers, ERDAS IMAGINE and ArcGIS software with extensions such as Spatial Analyst and Geostatistical Analyst. ERDAS Imagine is used to conduct land cover classification. ArcGIS is applied to link GWA water quality

data to well locations, and is utilized to evaluate the relationship between human-induced activities and groundwater quality.

Principal Findings and Significance

Erdas Imagine software is applied to derive the above mentioned land cover from satellite imagery, and change detection of land cover can be determined by temporal land cover information.

Based on the analysis of land cover information derived from Landsat MSS image of 1973 and QuickBird Image of 2006, most of the northern Guam was covered by vegetation, i.e., forest and grass in 1973 and 2006. The total area of forest increased by 14.4% from 1973 to 2006, while the total area of grassland decreased dramatically by 72.4% from 1973 to 2006. However, the total area of vegetation including forest and grass decreased by about 12.1% from 1973 to 2006, which could be accounted for by human-induced activities, particularly urban development in the past few decades in Guam. The urban area increased from about 22% to 30.3% between 1973 and 2006, and the trend will continue in the coming years because of extensive military buildup activities caused by the relocation of about 8600 marines from Okinawa to Guam up to 2014. The following table presents more details about land cover change from 1973 to 2006 in the northern Guam.

Land Cover Change Detection in Northern Guam from 1973 to 2006

| <div>1973 \ 2006</div> | Forest | Grass | Bareland | Urban | Water | Total |
|------------------------|--------|--------|----------|--------|-------|---------|
| Forest | 144808 | 9889 | 1289 | 19912 | 204 | 176102 |
| Grass | 36116 | 10327 | 1575 | 29286 | 312 | 77616 |
| Bareland | 163 | 35 | 13 | 72 | 0 | 283 |
| Urban | 20446 | 1169 | 677 | 49455 | 124 | 71871 |
| Total | 201533 | 21420 | 3554 | 98725 | 640 | 325872 |
| | | | | | | |
| | | | | | | |
| <div>1973 \ 2006</div> | Forest | Grass | Bareland | Urban | Water | Total |
| Forest | 82.23% | 5.62% | 0.73% | 11.31% | 0.12% | 54.04% |
| Grass | 46.53% | 13.31% | 2.03% | 37.73% | 0.40% | 23.82% |
| Bareland | 57.60% | 12.37% | 4.59% | 25.44% | 0.00% | 0.09% |
| Urban | 28.45% | 1.63% | 0.94% | 68.81% | 0.17% | 22.05% |
| Total | 61.84% | 6.57% | 1.09% | 30.30% | 0.20% | 100.00% |

Since the groundwater quality data provided by GWA is stored in Microsoft Excel spreadsheet format, it needs to be geocoded for further analysis in GIS. The geocoding process links the Excel spreadsheet data to well locations, therefore groundwater quality data can be saved in GIS formats, i.e., shapfiles for this research so that GIS can be

utilized to process and analyze the groundwater quality data to locate problematic wells. This project mainly focuses on commonly occurring contaminants such as fecal coliform, chlordane, PCE and TCE, locating problematic wells, and evaluating relationships between such contaminants and land cover change, particularly human-induced activities such as urban development. GIS-based analysis of the fecal coliform data from 1998 to 2009 indicates that the wells of A-23, A-25, A-30, A-31, EX-5A, F-4, F-11, F-17, Y-3, Y-9, Y-14 and Y-23 have problems with occurrences of fecal coliform (Figure 1). The wells of A-13, A-18, AG-1, D-7, D-19, D-20, D-22, F-19, M-9, Y-1 and Y-2 have potential risks in occurrences of fecal coliform (Figure 2).

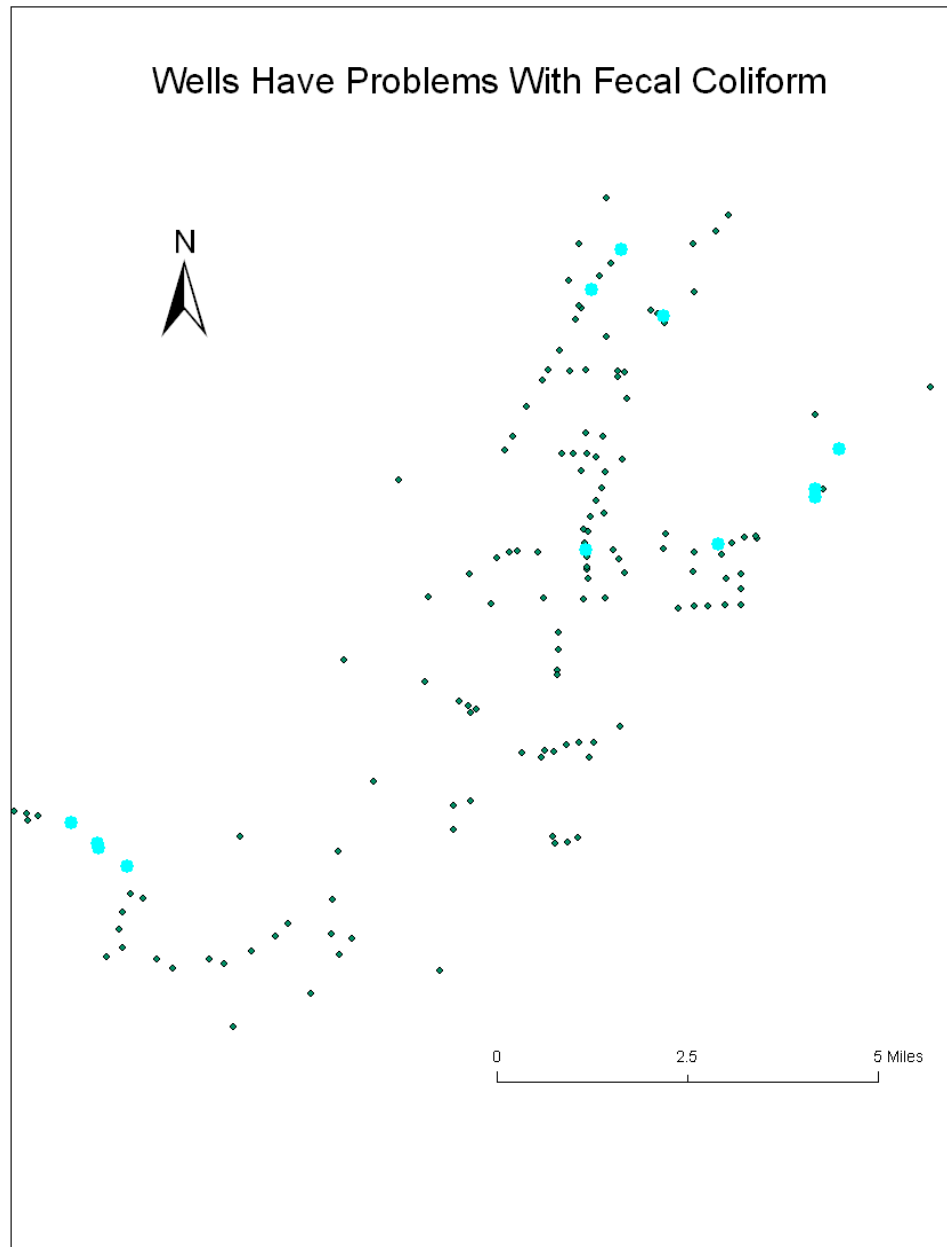


Figure 1. Wells with high frequency of occurrences of fecal coliform (Green dots)

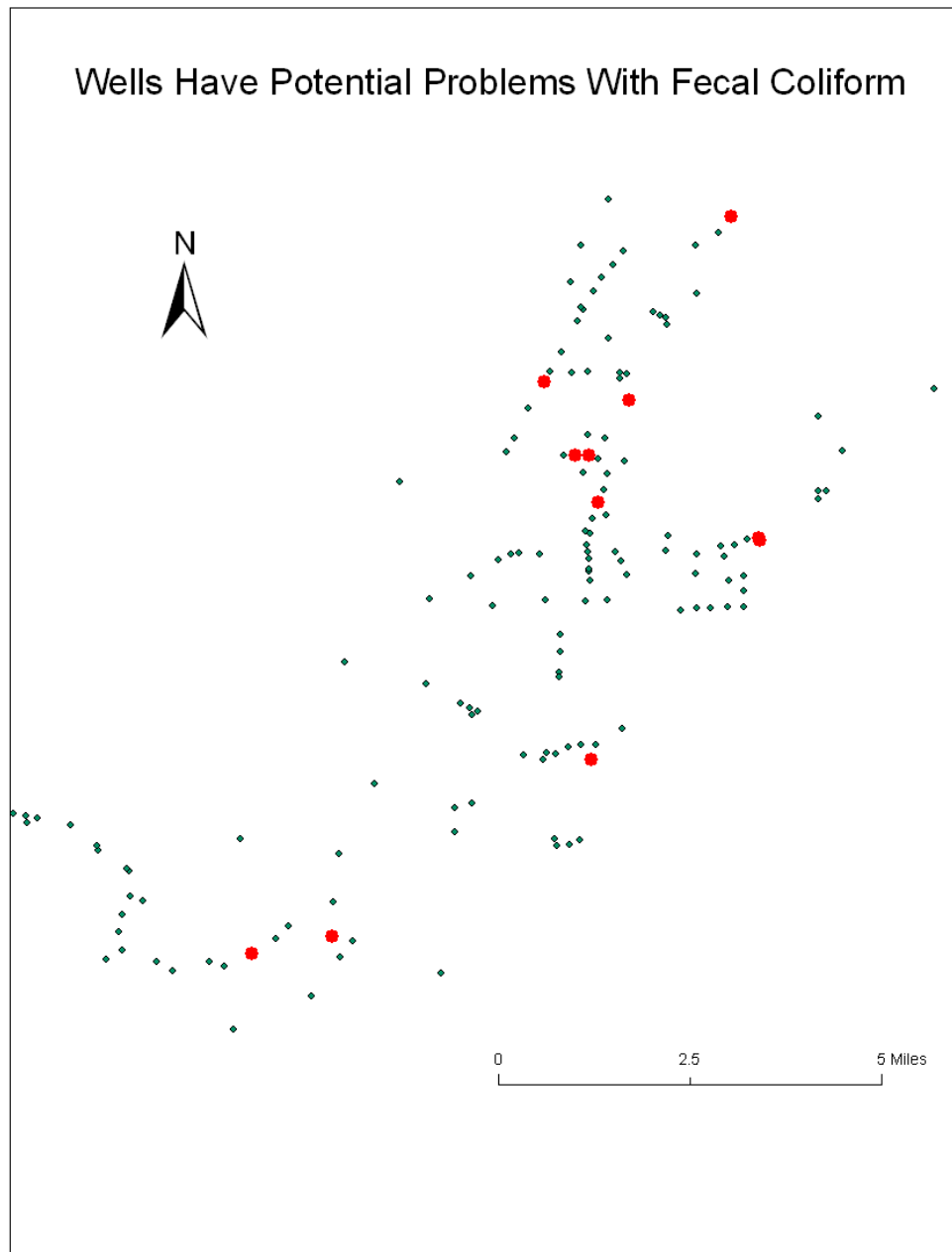


Figure 2. Wells with potential risk of occurrences of fecal coliform (Red dots)

When ArcGIS software is used to analyze the TCE data, no wells have problems with TCE. However, three wells, i.e., A-17, D-5 and NAS-1 have potential risk in high level of TCE (Figure 3).

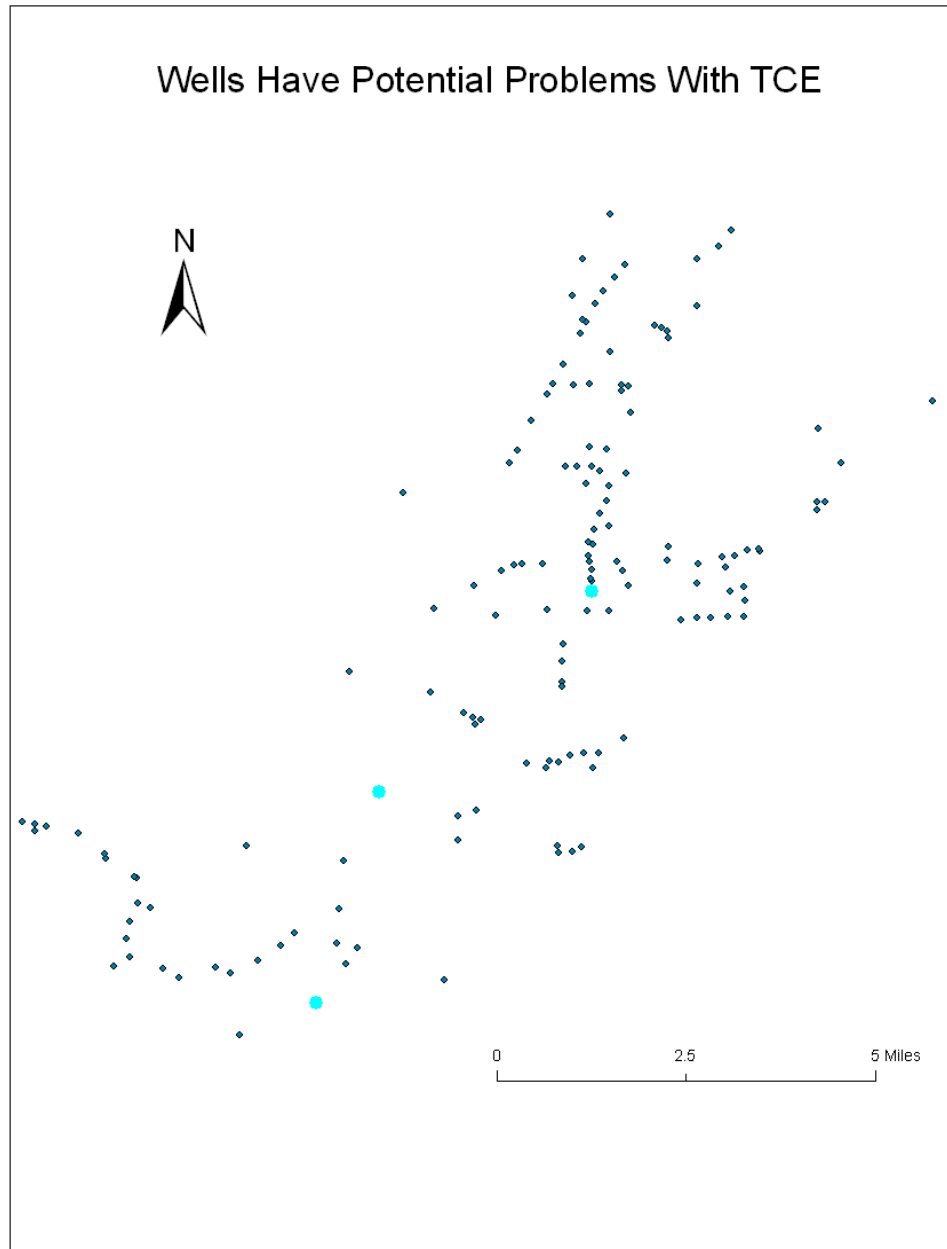


Figure 3. Wells with potential risk in high level of TCE (Green dots)

Query of the PCE data indicates that no wells have problems with PCE. Only two wells, i.e., A-5 and A-30 were detected low level of PCE in most of detection periods (Figure 4).

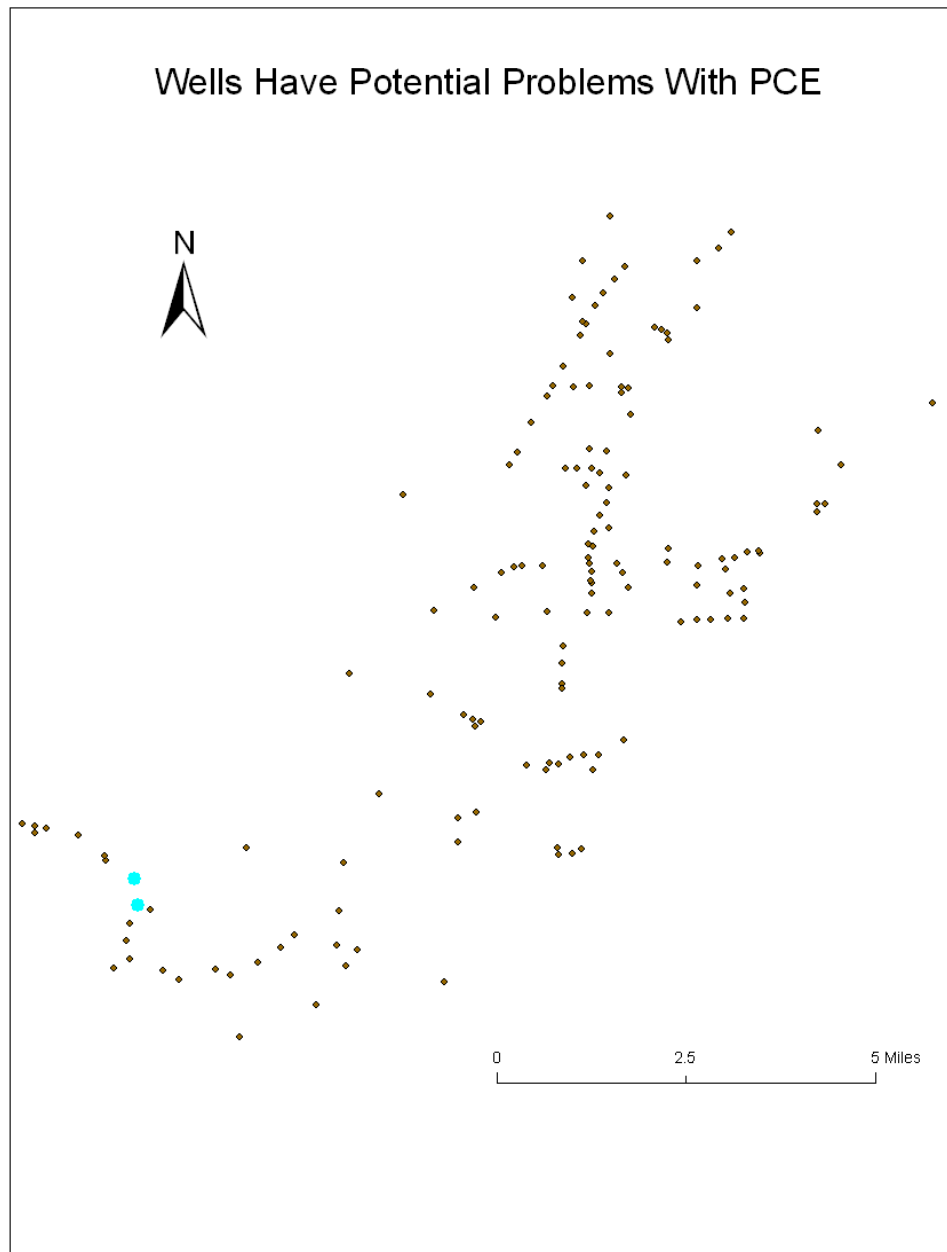


Figure 4. Wells with potential risk in high level of PCE (Green dots)

There are five wells with potential problems with chlordane contamination, though the chlordane contaminant levels for all of the wells did not exceed the maximum contaminant level (MCL). These wells are A-25, D-15, GH-501, M-14 and M-18, especially the well M-14 (Figure 5).

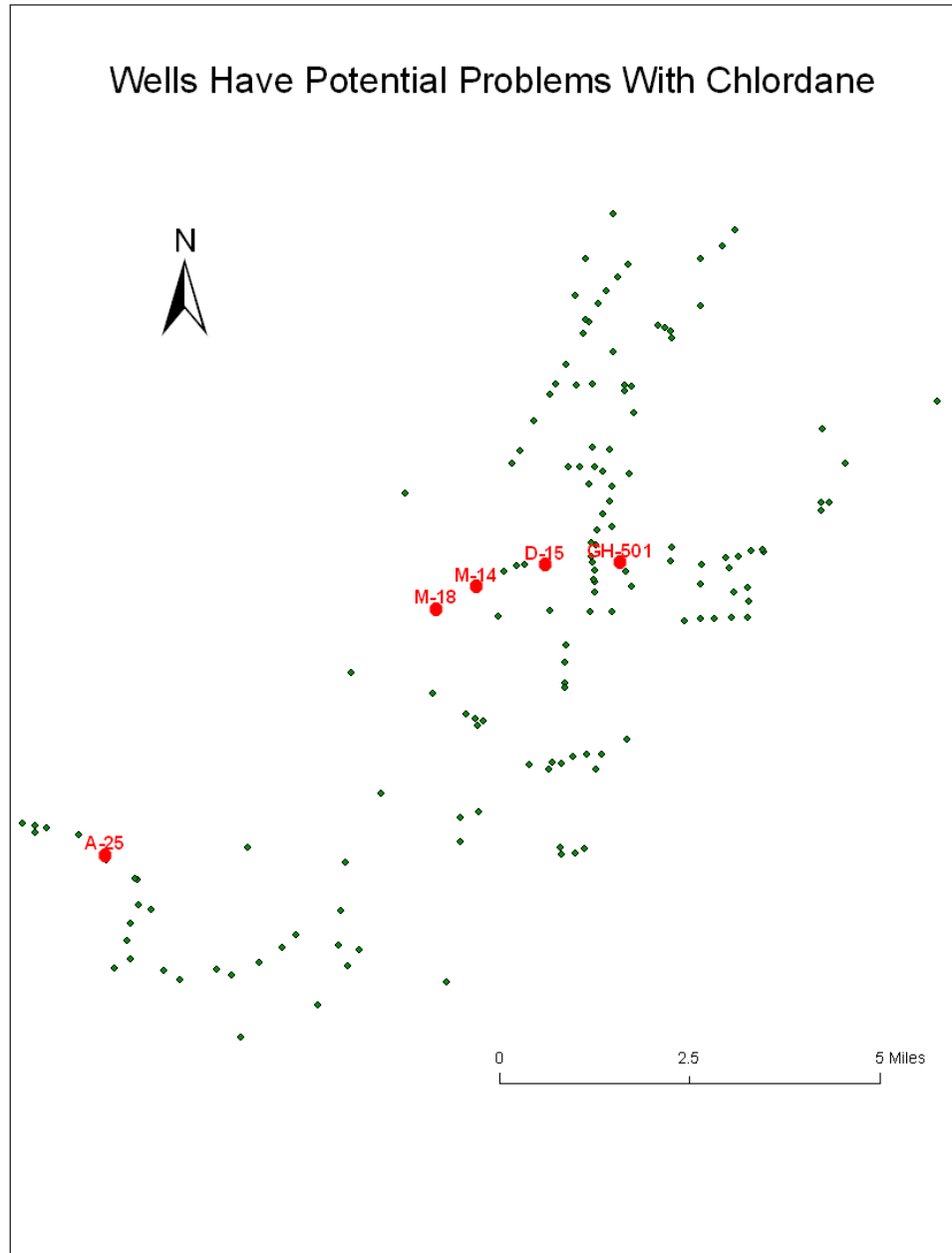


Figure 5. Wells with potential risk for chlordane contamination (Red dots)

Wells with potential PCE problems are located in urban areas. Wells with potential chlordane risk are located in grassland. Wells with fecal coliform problems are usually located in urban areas or close to urban areas. Wells with potential TCE contamination are also located in or close to urbanized areas. The change detection of land cover from 1973 to 2006 indicates that human activities, particularly urban development caused loss

of vegetation in the northern Guam. More impervious surfaces will be created with the upcoming military buildup activities in Guam.

The findings and methods used in this project are of interest to some agencies. The Government of Guam, and particularly GWA and Guam Environmental Protection Agency (GEPA) is interested in groundwater quality, land cover information, and land cover change. Groundwater quality data, and land cover information in different dates may help researchers, water resource engineers, land managers, local, state or federal government agencies, particularly GWA, GEPA and US EPA provide better groundwater management, and better understand how groundwater quality was affected by human-induced activities such land cover change. Such data or analytical results are also important to aquifer protection and environmental monitoring and analysis.